THE USE OF EXTREMELY LOW FREQUENCIES (ELF) IN PULSED FORM (PELF) FOR THERAPEUTIC USE: A PILOT STUDY

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Abstract **- Following a previous investigation on the therapeutic effects of Extremely Low Frequency in pulsed form - Pulsed Extremely Low Frequency (PELF) [1] - this research explores the possibility of detecting the effects of PELF on the biological system by the use of the Heart Rate Variability (HRV) analysis.**

There is no overall change in HRV in presence of very weak - less than 25 μT - PELF. However when the HRV is considered together with Heart Rate (HR) and Blood Pressure (BP) some interrelation can be detected.

Keywords **– Electromagnetic Fields, Magnetotherapy**

I. INTRODUCTION

The effect of Electro Magnetic Fields (EMF) on living tissues, in particular on human living tissues, has been widely explored. Emphasis has been given to the research on the effects of the EMF in the Radio Frequency (RF) range - targeting, in particular, the effects of mobile telephony radiation - and on the effects of the EMF in the Extremely Low Frequency (ELF) range (less than 100 Hz) - with particular reference to the effects of the EMF radiated by the main power distribution network (50 Hz and/or 60 Hz).

Usually, the aim of such investigations has been to categorise the effects of EMF from the pathological viewpoint based on the effect of these fields on human cells.

In 1999 the Bioelectronics Group of Monash University has looked into the possible therapeutic effects of the ELF EMF using commercially available units. The research did investigate the therapeutic effects of PELF EMF for the healing of soft tissue injury [1].

The question whether electromagnetic fields associated with magneto-therapy can have secondary biological effects beyond the targeted aim, e.g. repair of bone fractures or soft tissue injuries healing, is still matter of debate. Scientific and social investigations have been conducted to evaluate the impact of EMF on human health. Most of these researches have looked into the effects of EMF centred on the main supply frequencies of 50 Hz and 60 Hz. While most of the results are inconclusive with respect to genotoxic and carcinogenic effect of ELF EMF, it has been found that exposure to ELF EMF can alter the Heart Rate (HR) [2].

In 1996 the European Task Force has published a set of recommendation [3] to unify the research in Heart Rate Variability (HRV) to facilitate the interpretation and correlation of the data obtained in experiments. The power spectral range considered during HRV analysis is in the frequencies below 1 Hz. In the recommendation [3] the range of HRV the significant frequencies below 1 Hz have been classified as Very Low Frequency (VLF), Low Frequency (LF) and High Frequency (HF). The complete range of these frequencies spans from 0+ Hz to 400 mHz. The European Task Force also recommended the time length of the signal used for HRV investigation: short term (2 to 5 minutes) and long term (20 minutes plus).

The HRV spectral analysis may be conducted for qualitative and/or quantitative investigation. In the qualitative investigation an analysis of the frequencies, for each of the defined bands, where the peak spectral power is encountered are classified and related to known pathological and/or physiological status. In the quantitative investigation, instead, the spectral power ratio between bands it is considered. For this investigation the quantitative investigation has been used.

It is known [4] that the Autonomic Nervous System (ANS) controls the HRV. This control can be detected in the LF range for the sympathetic branch of ANS and in the HF band for the parasympathetic branch of the ANS. The latter is also known as vagal control.

In the quantitative investigation the HF/LF ratio is considered therefore the result is an indication of the sympatho/vagal modulation.

The effect of ELF EMF on HR can be considered similar to the biochemical effects mediated by the ANS [3]. The parasympathetic branch of ANS contributes to the reduction of HR via the release of acetylcholine. The sympathetic branch of ANS contributes to the increase of HR via the release of epinephrine and norepinephrine [3].

The spectral analysis is a fast, non-invasive method to detect in the short-term if PELF EMF, as used in magneto-therapeutic units, can affect the HRV. However this analysis in short-term cannot be qualitative, but only quantitative, based on the HF/LF ratio. The qualitative analysis requires a long-term test to allow the collection of biological contribution whose frequency is very low compared to the HR. The physiological correlates of ULF and VLF are still unknown [3]

II. METHODS

A. The radiating source

To perform this investigation two magneto-therapeutic units were considered:

- The Magnafield® Magnetic Induction Unit mod 998 - manufactured by Magnacare - South Australia

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Abstract

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- Magnetherapeutic Unit Mod 9800 – Magnetosan - manufactured by Beta Elettronica - Treviglio (BG) - Italy

The Magnafield® Magnetic Induction Unit mod 998 radiates a pulsed 50 Hz EMF - Pulsed Extremely Low Frequency (PELF) – The Pulse Repetition Frequency (PRF) is preselectable and varies from 0.5 Hz to 15 Hz.

The Beta Elettronica Mod. 9800 radiates a bipolar pulse at variable frequency (presettable) from 5 Hz to 100 Hz and with variable (presettable) field intensity from 3 to 100 gauss.

Figure 1 shows Magnafield and Beta Elettronica EMF spectrum

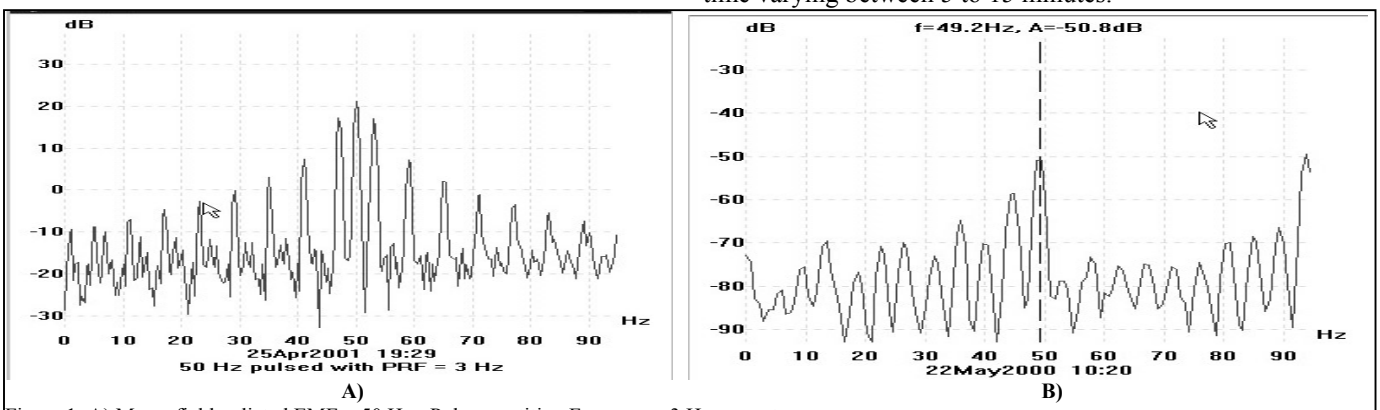

Figure 1: A) Magnafield radiated EMF - 50 Hz - Pulse repetition Frequency: 3 Hz. - spectrum
B) Beta Elettronica radiated EMF - nominal 50 Hz - spectrum

Analysing the waveforms and spectra obtained from the two magneto-therapeutic units it was decided to use the Magnafield unit for the following reasons:

- The radiated field is a sinusoid. The use of this characteristic can provide an insight on the possible effects of 50 Hz EMF radiated by over ground power lines.
- The pseudo-randomness given by the modulating frequencies can simulate the EMF gradients due to instantaneous load variation on the overground power lines.
- The power spectral distribution is almost symmetrical with reference to the central frequency of 50 Hz. The deviation from the central frequency follows the equation [5]:

$$F_1(\varpi) = 2\pi \sum_{-\infty}^{+\infty} BT_2 \left[\frac{\sin(\omega-\omega_1)T_2}{(\omega-\omega_1)T_2} + \frac{\sin(\omega+\omega_1)T_2}{(\omega+\omega_1)T_2} \right] \partial(\omega - n\omega_0) \quad (1)$$

typical of Pulsed EMF, where the delta function $\delta(\omega\text{-}n\omega_0)$ expresses the distance of the side-lobes from the centre frequency in function of the PRF.

- The Magnafield had been used in the previous therapeutic experiment [1]. The experiment demonstrated the validity of the magneto-therapy for the healing of injuries on soft tissue.
- As a follow-up, it would be of interest to explore if the biological system is affected by the possible existence of collateral effect associated with the fundamental frequency and its side-lobes at the various PRF used [6].

B. The experiment

Being a pilot investigation, only three subjects (two males and one female with age ranging from 25 to 65 years) have been used. This experiment duplicated the previous experiment [1], with the exception that no injury was induced in the subjects: two sets of 20-minute exposure separated by a 20-minute of non-exposure. This experiment is also described in [6].

The experiment may be classified as a "single blind" because the subjects were not aware of when the therapeutic cycle was started. The complete therapeutic cycle was composed of four stages (Blocks). The cycle stages are identified and referred to as:

Pre-Test = The time before the application of the EMF – time varying between 5 to 15 minutes.

EMF 1 = The time of the first EMF application - 20 minutes

Idle 1 = The time of non-radiation following EMF1 – 20 minutes

EMF 2 = The time of the second EMF application – 20 minutes

Idle 2 – The time following the second EMF application – time varying between 15 and 30 minutes.

The variable Pre-Test time was used as uncertainty factor for the actual starting of the therapeutic cycle.

The therapeutic unit control panel and the data acquisition monitor are not readable by the subject.

The EMF was directed towards the subject's hips. The pattern of the EMF is circular centred at the exciter coil centre. The subject is sitting on a polycarbonate chair and the radiating coil is situated at 40 cm from the target area. The subject is not required to control his/her breathing rhythm and is allowed to perform small actions such as operating a computer or reading.

The above-described conditions have been chosen to duplicate a therapeutic clinical setting.

The HR and BP data were collected using an automatic, self-calibrating Blood Pressure unit - MARS Mod. MS-700. The cuff is connected to the subject's left arm.

The ECG data were obtained using the BioPac system MP100WSW that includes both hardware and software for the acquisition and analysis of life-science data. Two electrodes were placed at the top of the subject's chest – scapular area – to form a Lead II configuration. To conform to the European Task Force recommendation [3] for short term

analysis, each ECG recording section lasted three minutes, the sampling rate was of 1000 sample/sec, giving a total of 180,000 sample per section.

The BioPac software was used for the evaluation of the Power Spectrum Density (PSD) of the ECG as required for the evaluation of the HF/LF ratio. The evaluation of the HF/LF ratio - suggested by the European Task Force [3] is the method used to evaluate the sympatho-vagal interaction. For the evaluation of the PSD two methods have been used:

- Using logarithmic scale: Fast Fourier Transform (FFT) - Blackman window. The result was in magnitude (dB) versus frequency. The PSD in $msec^2/mHz$ was evaluated, using the BioPac software, from the logarithmic scale.
- Using linear scale: FFT - Hamming window. The result was in amplitude versus frequency. The PSD was evaluated, using the BioPac software, from the linear scale and then normalised to obtain the $msec^2/mHz$ form.

III. RESULTS

Before starting the sets of experiment the value of the EMF in situ was measured at the various PRF. The EMF intensity was of 15.15 μT ± 0.5 μT in the PRF range.

The results may be presented in Pie Chart format as suggested by Anonymous [3]. Figures 4 and 5 show the results of the experiment 4D for the subject 4. Figure 4 is the HF/LF ratio for the total averaged data. Figure 5 is the HF/LF ratio for each of the test's sections.

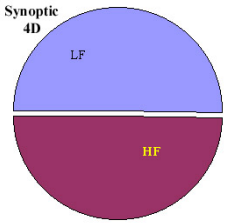

Figure 4 – HF/LF ratio (normalized units) for the Synoptic data of Experiment 4D

The linear graph, however, gives a better picture of the HF/LF ratio changes for each of the five stages of the test - figure 6.

The linear graph evidences the changes in HF/LF ratio at each sequential test. The test blocks, described in the method section, are identified and superimposed to the graph.

The linear graph is now used in figure 7 to show the changes in Heart Rate (HR) and Blood Pressure (BP) with reference to changes in HF/LF ratio.

IV. DISCUSSION

The results from this experiment should be analysed both at macro or overall level and at micro or particular level.

A. Macro Level

At this level, the data seem to validate the result obtained by Graham [7] that a 50 Hz EMF does not alter the long-term HRV power ratio. The validation can be seen looking at figure 4 and at figure 5A. It is important to recall here that the values shown in Figure 4 and figure 5 are "averaged" data.

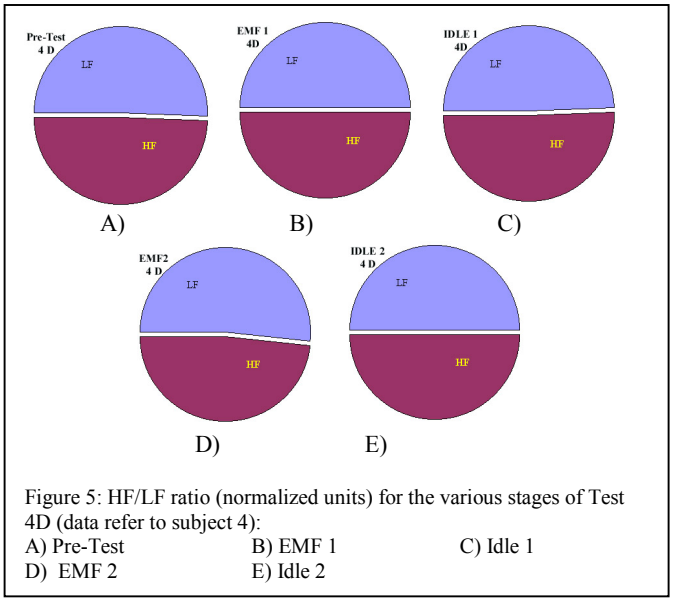

Figure 5: HF/LF ratio (normalized units) for the various stages of Test 4D (data refer to subject 4):
A) Pre-Test B) EMF 1 C) Idle 1
D) EMF 2 E) Idle 2

Figure 5A shows the initial HF/LF ratio. The data refer to the sympatho-vagal balance before the magneto-therapeutic treatment. Figure 4 shows the "overall" sympatho-vagal balance obtained by the averaged value of all the collected data.

Both figures show a similar pattern in the pie chart. This can be interpreted as the fact that after one hour of exposure to the electro-magneto-therapeutic field the HRV does not show an appreciable change in the sympatho-vagal system.

However the macro approach does not give an indication of the HF/LF ratio modulation during the experiment.

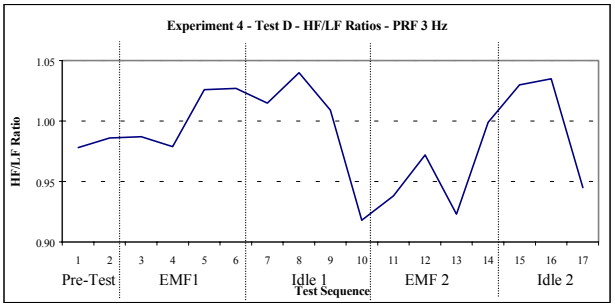

Figure 6: HF/LF linear graph for each sequential test.

B. Micro Level

At this level differences can be noted for each of the steps of the magneto-therapeutic treatment.

The first noticeable effect is in figure 7B: systolic and diastolic pressures tend to converge. The first indication of convergence can be found at the transition from rest (Pre-test) to the first application of the EMF. (Data collection 2)

Similar convergence can be found at every transition from the EMF to Idle and vice versa. A summing or "storage" effect leads to an accentuation of the systolic-diastolic blood pressure value convergence.

The blood pressure convergence effect has been noticed at all the various PRF used for the experiment. The increase

in PRF seems to emphasise the convergence, with particular reduction in value for the systolic blood pressure.

This variation in the blood pressure could be attributed to the different side-lobes that can be detected in the spectral analysis at different PRF as consequence of the delta function in (1)

The variation in systolic and diastolic blood pressure has also been noted in all subjects.

However there is a difference in time response between subjects. This difference could be attributed to the individual level of electrosensitivity.

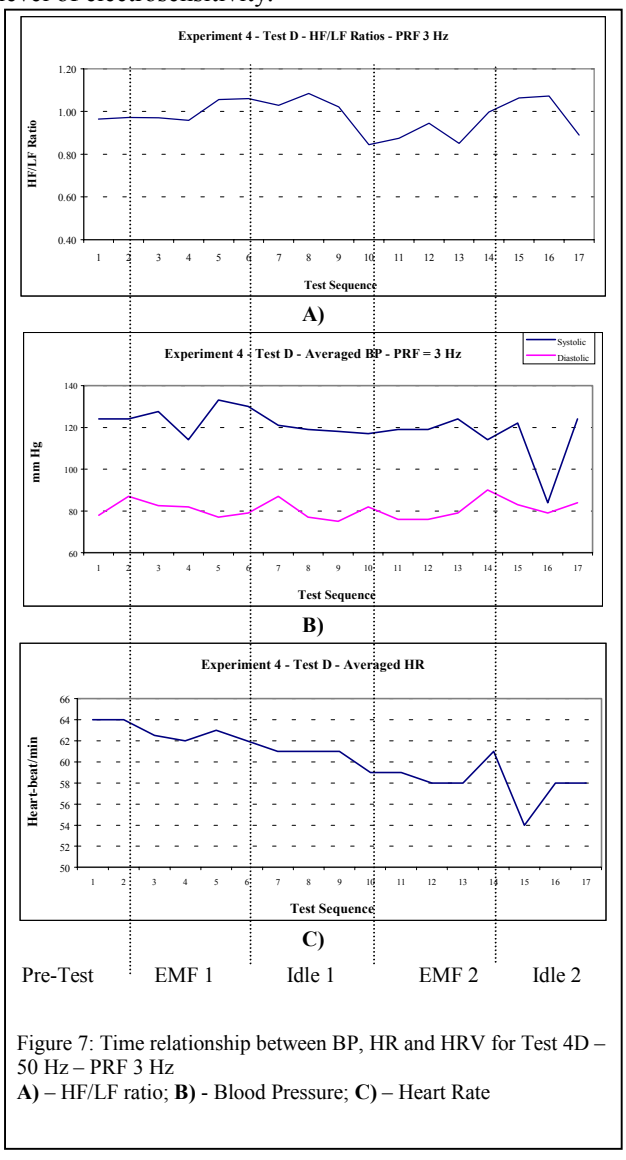

Figure 7: Time relationship between BP, HR and HRV for Test 4D – 50 Hz – PRF 3 Hz
A) – HF/LF ratio; **B)** - Blood Pressure; **C)** – Heart Rate

V. CONCLUSIONS

Statistical data have not been evaluated because of the small population sample.

The inspection of the graphs shows for the subject 4 a constant decrease in HR.

This decrease has a marked steep valley at the end of the second application of EMF (EMF2).

The change in heart rate and blood flow can give an insight to the mechanics of the magneto-therapy.

Sisken [8] stipulates that changes in blood flow at tissue lesion points may be cause restoration of capillary blood flow in the damaged areas with consequent effect of accelerating the healing process.

More investigation is required into the interaction of HRV, HR and BP when the biological system is exposed to ELF pulsed in cyclic or random mode.

Particular attention should be given to the effects of the side-lobes that seem to contribute to a variation in the systolic blood pressure.

Future investigation will find some answers on the topic of magneto-therapy and, as by-product, a possible better understanding of the effects due to the everyday exposure of the biological system to the 50 Hz power distribution networks.

In particular, the investigation on the effects due to the transients originated by the PRF during the therapeutic treatment could lead to an understanding of the controversial results obtained from the exploration of effects originated at main power frequency.

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